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State-of-the-Art Assessment of Methane-Fueled Vehicles

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February 1982

U.S. Department of Energy
Assistant Secretary, for Conservation
and Renewable Energy
Office of Vehicle and Engine R & D

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II

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Washington, D.C. 20585

III

STATE-OF-THE-ART ASSESSMENT OF METHANE-FUELED VEHICLES

1. INTRODUCTION

The Methane Transportation Research, Development, and Demonstration Act of 1980 (PL 96-512) focused on the expanded use of methane as a fuel for fleet-operated vehicles. In formulating the Act, Congress found that:

- Methane use in fleet-operated vehicles would result in a substantial reduction in oil imports with the potential for concurrently reducing vehicle emissions.
- Methane, now found principally in natural gas, is presently underutilized in the United States. Alternative sources for increased quantities of methane in the future include coal, biomass, waste products and other renewable resources.

Implementation of the Act is the responsibility of the Department of Energy's (DOE's) Office of Vehicle and Engine R&D. Section 7 (a) of the Act requires DOE to assess the current state-of-the-art of methane-fueled vehicles by 1 January 1982 to develop baseline data for evaluating potential improvements in applicable vehicle technologies. This report is intended to fulfill this requirement.

Following the definitions provided in the Act, the term "methane" as used in this report includes, and is interchangeable with, natural gas as well as gas derived from coal, biomass, waste products or other renewable resources, provided methane is the predominant constituent. Methane is considered to have application as a vehicle fuel in the form of either compressed natural gas (CNG) or liquefied natural gas (LNG). Finally, the Act defines the term "vehicle" to mean any truck, bus, car, station wagon or van operated on public roads or highways, as well as off-road agricultural vehicles.

This assessment is based primarily on data from a study conducted by The Aerospace Corporation for DOE's Office of Vehicle and Engine R&D. The final report on this study, which documents study findings, is available for inspection in DOE's Freedom of Information Reading Room (Room 1E-090, Forrestal Building, 1000 Independence Avenue, SW, Washington, D.C.).

2. ADVANTAGES AND DISADVANTAGES OF METHANE FUEL

Methane, in the form of natural gas, has been utilized as a vehicle fuel for many years in Europe but it did not generate significant interest in the United States until the late 1960s. At that time, the impetus for the introduction of methane-fueled vehicles was the alleviation of air pollution through reduced exhaust emissions. Later, tight gasoline supplies during the Arab Oil Embargo of 1973, soaring costs of gasoline in the late 1970s, and increased availability of natural gas in current markets have fostered increased interest in methane as an alternative to gasoline.

2.1 ADVANTAGES

Methane possesses many favorable attributes as a vehicle fuel. It is particularly suitable for spark ignition (SI) engines, which can be converted by adding a methane storage and feed system to permit operation on either gasoline or methane.

On an equal energy basis, CNG and LNG are currently priced significantly lower than gasoline with the probability that they will continue to maintain an appreciable cost advantage for the user. Methane's principal feature as a fuel for SI engines is its high research octane number (RON) of 130, which permits the use of high compression ratio engines in vehicles designed specifically for methane, with accompanying efficiency benefits. In addition, the broad flammability limits of methane allow efficient engine operation with lean air-fuel mixtures, and the gaseous state of the fuel reduces engine pumping losses by decreasing the degree of throttling required for a given power setting. With regard to exhaust emissions, the simple chemistry of methane is beneficial, leading to low engine deposits and low hydrocarbon emissions. Also, much of the hydrocarbon emissions is comprised of non-reactive methane, thus potential adverse impacts on public health and the environment are considerably lower than for conventional fuels. Furthermore, methane has thus far proved to be a safe vehicle fuel, although the data base is substantially less extensive than for petroleum fuels.

From the national standpoint, a very important advantage of methane is the potential displacement of substantial quantities of petroleum by domestically-produced gas, which enhances U.S. security and improves the country's balance-of-payments position.

2.2 DISADVANTAGES

Inasmuch as methane is a gas at atmospheric conditions, it must be stored onboard the vehicle as either a compressed gas or cryogenic (very low temperature) liquid at the present state of technology. Other storage concepts, such as adsorption on activated carbon, are under investigation by industry in an effort to reduce weight, volume, and handling problems associated with current approaches. For example, the use of a two-cylinder CNG system presently adds between 250 and 300 pounds to the weight of the vehicle and occupies a significant fraction of a car's trunk volume, while providing a range of only 60 to 120 miles. Conversely, an LNG single-fuel system weighs approximately the same as a gasoline configuration but occupies about twice the volume, while providing a range of 300 to 400 miles.

Because of methane's gaseous state, its use results in a moderate reduction in peak engine power due to air displacement in the intake system. Another unfavorable property of methane is its low flame speed which tends to decrease the thermal efficiency of spark ignition engines. However, much of this latter loss may be recovered by means of spark timing optimization. Finally, the low cetane number of methane makes it unsuitable as the sole fuel for conventional diesel engines. However, as discussed in Section 3.3, methane may be used in diesel engines in conjunction with pilot injection of diesel fuel or other techniques.

3. VEHICLE SYSTEM STATUS

Over 250,000 vehicles in Italy, more than 20,000 in the United States, and lesser numbers in other countries are currently capable of operating on methane. These vehicles have, almost exclusively, carbureted spark ignition engines, converted to operate in a dual-fuel mode on either CNG or gasoline. Conversion kits of both domestic and foreign designs are commercially available for these engines from several suppliers. CNG systems are sold by Dual Fuel Systems, Inc.; Gas Service Energy Corporation; Advanced Fuel Systems, Inc.; Essex Cryogenics, Inc.; Dual Energy Inc.; CNG Services, Inc.; CNG Fuel Systems Incorporated of Canada; and Auto Italia of Italy.

Vehicles converted to LNG are much fewer in number. At present, there is only one large utility car and light-duty truck fleet of over 100 vehicles in operation, that of the Atlanta Gas Light Company. Two currently active developers/producers of LNG conversion kits are Beech Aircraft Corporation and LNG Services, Inc. However, Essex Cryogenics, Inc., Kaiser Electro Precision, and Gibson Cryogenics have built conversion equipment in the past and might reenter the market if there were a resurgence of LNG system orders.

Vehicles designed to obtain optimal efficiency from methane fuel are in the development and demonstration stage at this time. Because of the significant engine design changes required, e.g., compression ratios of 12 to 14 and basic spark advance of about 20 degrees before top center (BTC), satisfactory operation on the relatively low octane gasoline currently marketed by domestic refiners is not possible. Single fuel CNG and LNG vehicles have recently been built, but only limited performance data are available. A major problem in the use of CNG is the achievement of adequate vehicle range without incurring excessive storage weight and volume penalties.

Conversion of compression ignition (CI) engines to methane operation is difficult because of the very low cetane number of the gas. Only experimental vehicles have been operated to date and no conversion kits are commercially available.

Currently, the cost of new CNG or LNG conversion systems is in the range of $1200 to $2000 per vehicle. In addition, since there is no publicly-available supply system in place at this time for either CNG or LNG, each user must provide his own fueling facilities. For this reason, implementation of methane fuel is presently confined to fleet operators. In the case of CNG, complete compressor station installations are commercially available from several suppliers, adding about $1000 to $2000 to the conversion cost of each vehicle served by the station. Production of LNG requires a fairly large and sophisticated plant, typically owned by natural gas distribution companies for peak load shaving needs. For this reason, the only current, large LNG fleet is operated by the Atlanta Gas Light Company. However, it may be feasible to locate LNG fleets some distance from such peak shaving plants and transport the fuel by tank truck, rail or pipeline to a storage tank on the premises of the fleet operator.

The number of fleet vehicles that are potential candidates for methane conversion is large, and the accompanying petroleum savings would be

significant. Commercial, industrial, and governmental passenger car fleets total approximately 13 million automobiles, which currently consume more than 1 million barrels of petroleum per day, approximately 95 percent of which is gasoline. At least 10 passenger vehicles may be needed in a fleet to justify the capital investment in dual-fuel CNG or LNG vehicular and fueling systems. There are approximately 4.8 million vehicles in fleets of this size, currently consuming 0.4 million barrels of petroleum fuel per day. For an estimated 90 percent natural gas usage, the petroleum savings potential is approximately 0.35 million barrels per day.

In the case of trucks, six or more vehicles may be needed in a fleet to justify the capital investment in vehicular and fueling systems. Currently, the candidate truck fleet vehicles number 4.2 million and consume about 1 million barrels of petroleum fuel per day, of which 25 percent is gasoline. For an estimated 90 percent natural gas use in spark ignition engines and maximum estimated gaseous fuel utilization in diesels, the petroleum savings potential is appproximately 0.8 million barrels per day.

3.1 CNG SYSTEMS FOR SI ENGINES

The principal type of dual-fuel conversion system for CNG marketed in the United States consists of one or more compressed gas steel storage cylinders, high-pressure tubing leading to a first stage high-pressure regulator assembly, an interstage solenoid shutoff valve, a second stage low-pressure regulator which provides gas to a gas-air mixer, a fuel pressure gauge, and a manual fuel selection device operated from the driver's seat. Fuel switching between gas and gasoline can, in most cases, be accomplished while driving. The gas cylinders are loaded to about 2400 pounds per square inch (psi) through a fill connection on the high-pressure delivery line that is located in the engine compartment.

On the basis of lower heating values for typical natural gas and gasoline, 125 standard cubic feet (scf) of gas are equivalent to one gallon of gasoline. Since a typical steel CNG cylinder stores 325 scf of natural gas at 2400 psi, each cylinder contains the equivalent of approximately 2.8 gallons of gasoline. Industry "rules of thumb" often cite equivalency factors of 100 scf per gallon of gasoline, implying a significant improvement in energy efficiency for gas. However, there is a lack of good substantiating data to justify the general application of the more optimistic factor.

In general, no changes are required to the SI engine other than replacement of the air cleaner with the gas-air mixer and, perhaps, spark timing advance to partially restore engine power in the gaseous fuel mode. The advance must be limited to avoid significant increases in engine knock and exhaust emissions when operating in the gasoline mode. The California Air Resources Board (CARB) currently does not permit spark advance relative to the vehicle manufacturer's recommendation for gasoline due to unknown impacts on exhaust emissions. However, at least one company intends to obtain CARB approval of a spark advance device for CNG fueled automobiles in the near future.

The steel cylinders are normally located in the car trunk over the wheels because of their size (1.5 cubic feet each) and weight (108 pounds each), and are firmly attached to the vehicle by mounting straps or brackets. Each cylinder has a manual shutoff valve and an automatic safety

relief device sensitive to pressure and temperature rises. To prevent accumulation of gas leakage from the manual cylinder refueling valves or the pressure relief devices into the vehicle trunk and the passenger compartment, some type of vapor barrier is generally installed. Discharge of such leakage outside the vehicle body shell leads to rapid dissipation into the atmosphere. Other passive and active venting techniques, such as foam barriers and fans, have been investigated for the trunk and passenger compartments.

Steel cylinders designed to Department of Transportation (DOT) Specification DOT3AA are intended for use in transporting industrial gases, including methane, but are not intended for use with natural gas or potentially corrosive gases. However, 10-inch diameter, 2400 psi operating pressure cylinders are widely used in the U.S. with natural gas. They are substantially heavier than the more highly stressed cylinders made in Italy for vehicle use which do not meet DOT requirements.

Both domestic and foreign CNG kit marketers have been developing lightweight cylinder designs, but such units have seen only limited use to date. Lightweight design approaches for automotive applications, where cost is a major consideration, include the use of aluminum alloys and composite structures.

Aluminum alloys have been used in the fabrication of pressure vessels, but their weight advantage relative to steel is only about 30 percent and costs are higher. Composite pressure vessels, consisting of a metallic inner shell and a layer of reinforcing fibers such as fiberglass or an organic polymer, Kevlar, offer a 50 percent weight reduction potential and other advantages for portable cylinder applications. The shell material may be chosen primarily for compatibility with its contents and the overwrap can bear most of the pressure loads without any weakening from attack by the tank's contents.

The use of hoop windings only for shell reinforcement yields the most easily manufactured and least expensive composite cylinders. For a 325 scf hoop wound cylinder, weight is estimated at 62 pounds (43 percent reduction over steel) and, in mass production, a cost about equal to steel cylinders ($200.00) is projected.

Two gas feed system problem areas that have not yet been completely resolved relate to regulator icing and excess flow shutoff valves. In the former case, despite various heater and other mechanical features incorporated in some regulator system designs, particularly of foreign manufacture, icing problems have been encountered at ambient temperatures even above freezing. Most domestic CNG users either dry the pipeline gas before compression or add a small amount of methanol to the CNG leaving the compressor. With regard to the second problem, an excess flow shutoff valve is intended to prevent complete discharge of the contents of a CNG cylinder in the event of a rupture in the high-pressure line. However, a satisfactory design has not yet been achieved. The principal difficulty is developing a valve which can successfully operate only when needed over the full range of pressures and flow rates experienced in normal vehicle operation.

3.2 LNG SYSTEMS FOR SI ENGINES

A typical LNG system for automotive applications consists of a double-wall cryogenic liquid tank mounted in the trunk, a valve assembly or

module for filling, venting and transferring fuel in liquid or vapor form to the engine compartment, a heat exchanger for vaporization and/or heating of the fuel, a low-pressure regulator, a gas-air mixer, fuel switching provisions, and associated low-pressure plumbing, gauges, and support members. It may be supplemented with an optional spark advance device, a gas leakage detector, a compartment isolation membrane, and vents for the vehicle passenger and trunk compartments.

The cryogenic tank is the heart of the LNG system, accounting for most of its volume, weight, cost and operational constraints. It features double-wall construction with the inner shell thermally isolated from the outer shell. The isolation provisions include a high vacuum to minimize thermal conduction and convection, and multilayer super-insulation to minimize radiation between ambient and cold surfaces. Operating tank pressures are usually about 5 to 60 psig. Beech Aircraft Corporation (BAC) claims to have achieved a 14 day standby condition with a totally filled tank without pressure relief.

Domestic tank producers have typically fabricated cylindrical designs with elliptical heads although spherical and oblate spheroid configurations have been used. Tank capacities range from 18 to 70 gallons. The 18 gallon tank was used by BAC in its Pontiac Phoenix demonstration vehicle; it has an outside diameter of 14 inches, a dome-to-dome length of 41 inches and weighs about 70 pounds empty. Materials range from aluminum for both inner and outer walls to combinations of stainless steel inside and aluminum for the outside shell.

Tank operation may be based on either vapor or liquid removal, or a combination of both, utilizing a flow control valve activated by a tank pressure signal. Liquid removal results in less fluctuation of tank pressure.

The principal differences between domestic cryogenic tank designs are the manner of supporting the inner tank from the outer tank and the number of layers of super-insulation used to minimize liquid boiloff. Such features directly affect tank cost and ruggedness, in terms of ability to withstand acceleration loads in a vehicle crash. LNG tanks are decidedly more susceptible to internal damage and penetration than CNG tanks. They should rupture with less violence, but would typically release much more chemical energy.

Two single-fuel LNG automobiles, a Mercury Zephyr and a Pontiac Phoenix, have been displayed recently, both based upon BAC systems. Ford's experimental Zephyr is equipped with a four-cylinder, 2.3-liter engine, with the compression ratio increased to 14 by means of special pistons. Basic spark timing is 20°BTC. The trunk-mounted LNG tank has a liquid capacity of 18 gallons. BAC has installed the same type of LNG system in a 173 cubic inch displacement (CID) engine-equipped 1980 model year Pontiac Phoenix with four-speed manual transmission. With a fully-loaded fuel tank and optimal spark advance, BAC reports a range of 380 miles, or 21.4 miles per gallon of LNG.

3.3 CNG AND LNG FOR CI ENGINES

Associated with the high octane number of methane is a very low cetane number. Therefore, the gas is unsuited for direct use in conventional diesel engines. However, in conjunction with chemical or thermal ignition aids, it can be burned satisfactorily.

Chemical ignition aids can take the form of fuel additives or, alternatively, a "pilot" injection system may be employed. With the pilot system, a secondary injector provides a small amount of high ignition-quality fuel, such as diesel fuel, to the combustion chamber, where it spontaneously ignites and burns the methane in the remainder of the charge. The primary fuel can either be injected or inducted via the intake manifold similar to SI engine practice (fumigation). Thermal ignition aids include spark plugs, glow plugs, or any other hot surface, possibly with a catalytic coating.

Fumigation with diesel fuel is currently favored since it is the easiest approach for a retrofit application. One benefit of fumigation is better mixing of the air and primary fuel than is achieved with injection. Another advantage is the reduction in smoke emissions caused by the predominance of methane, which is highly resistant to soot formation. Since rated diesel power output is usually smoke-limited, a reduction in smoke emissions can improve engine power, up to the knock limit.

A disadvantage of fumigation is the production of higher hydrocarbon (HC) emissions compared to diesel fuel alone. Oxides of nitrogen (NO_x) emissions are lower at part load, but at full load, the overall air-fuel ratio is close to stoichiometric, and there is no longer a NO_x advantage. Emissions of carbon monoxide (CO) tend to be higher; both CO and HC emissions can also increase at low load if the pilot/primary fuel ratio is not adjusted to prevent lean flameout in the bulk air-fuel mixture.

The diesel pilot accounts for 25 to 35 percent of total engine fuel at full power in the case of fumigation but only 5 to 10 percent with direct cylinder injection. As power decreases, the pilot charge makes up an increasing percentage of the total fuel. This variable pilot/gaseous fuel ratio requires a sophisticated control system for optimum fuel utilization. To date, the use of natural gas in diesel engines has been restricted to stationary or marine engines. Since such engines typically operate at constant speed and load for long periods of time, there is little need for such complex automatic controls.

4. CNG AND LNG VEHICLE OPERATING CHARACTERISTICS

Fuel economy, performance and emissions of methane-fueled spark ignition engines depend heavily on the degree to which the engine calibration and hardware have been designed to take advantage of the favorable characteristics of this fuel compared with gasoline. Most available data are not based on optimal systems, and a conclusive assessment of the ultimate potential of methane is difficult at this time.

4.1 FUEL ECONOMY

The use of CNG or LNG in pre-1975 model year vehicles without emission control system modifications has resulted in reported fuel economy improvements of up to 10 percent in passenger cars and up to 20 percent in trucks, relative to vehicle operation with gasoline. These improvements are primarily attributed to the relatively low fuel economy of the baseline gasoline vehicles which generally are calibrated for operation with rich

air-fuel mixtures. The fuel economy of late model automobiles operated on methane without modification in spark timing or other emission control system components is approximately equal to the fuel economy obtained with gasoline, when adjusted for differences in fuel heating value. Significant improvements in the fuel economy and power output of CNG and LNG vehicles have been achieved by specific fleet operators by means of spark timing advance and modifications of other emission control equipment. However, such modifications may increase exhaust emissions.

4.2 PERFORMANCE

A number of dual-fuel vehicle fleet operators have reported engine power reductions with methane, ranging from 10 to 20 percent relative to vehicle operation on gasoline. These losses are directly related to the reduction in engine volumetric efficiency, the lean air-fuel mixture calibration, and the use of non-optimum spark advance. In dual-fuel installations, engine power can be restored, at least partially, by means of spark advance and mixture enrichment. However, these calibration adjustments may increase exhaust emissions beyond permissible levels.

In a vehicle designed for methane, the power loss problem may be eliminated by increasing engine compression ratio to about 13:1, advancing spark timing relative to gasoline settings, incorporating a turbocharger, or a combination of these techniques.

4.3 EMISSIONS

Test data provided by several fleet operators indicate large emission reductions with CNG, amounting to 45 to 65 percent for HC, 60 to 80 percent for CO, and 50 to 80 percent for NO_x. These reductions are attributed to two basic factors: (1) unlike gasoline vehicles, CNG-fueled vehicles are generally operated at lean air-fuel mixtures, which is beneficial from an emissions point of view; and (2) the vehicles were older models using relatively rich air-fuel mixtures in the gasoline mode. In late model catalyst-equipped automobiles, use of CNG has resulted in significant reductions in NO_x and CO. While total HC emissions generally increase, the fraction of reactive species declines significantly. In a recent DOE-sponsored test, the fraction of non-methane HC emissions was found to be about 13 percent, in agreement with determinations of the California Air Resources Board. This is particularly encouraging in view of the EPA Notice of Intent for amending vehicle emission standards to permit compliance with a non-methane hydrocarbon standard (46-FR-21628; April 13, 1981).

5. SAFETY

The safety of CNG and LNG vehicle systems remains an important issue that has not yet been completely resolved. Only a few non-collision related incidents have been reported in which the natural gas system was identified as the source of a fire, attributed to faulty installation or venting deficiencies. However, the mileage that has been accumulated by methane vehicles is low compared to gasoline. Since accident-related,

gasoline-fueled automobile fires occur at a rate of only about one per 100 million vehicle miles, the fact that none has been encountered with methane is not statistically significant. Also, the excellent safety record compiled in Italy on CNG cannot be confidently extrapolated to U.S. usage inasmuch as cylinder designs, safety devices and administrative procedures differ considerably between the two countries. In the testing area, a safety impact test program conducted in 1971 for DOT included barrier crash tests of CNG dual-fuel vehicles, drop tests of CNG cylinders, and sled tests of CNG and LNG storage tank restraining systems. However, the vehicles, fuel systems and test conditions were not representative of current design practices.

The major safety concerns associated with methane-fueled vehicles under normal operating conditions are fuel leakage, boiloff of LNG vapor, and corrosive failure of CNG cylinders due to excessive concentrations of hydrogen sulfide (H_2S) in natural gas. A number of specific design steps can be employed to control these hazards, including isolation of fuel system components, venting of the passenger compartment and/or the space used for fuel storage, and the use of odorants and gas-sensing devices. Potential problems related to system corrosion may be eliminated by maintaining quality control of the fuel supply.

The hazards associated with methane vehicles under accident conditions include fuel release upon impact, tank rupture due to fire, and intrusion of fuel storage components into the passenger compartment. Lightweight CNG tanks of filament reinforced materials appear to be more susceptible to impact damage and require confirmation of crash integrity.

One area of concern is that there are no industry-wide standards regarding the design, manufacture, installation and performance of CNG fuel systems although efforts are underway, notably within the American Gas Association, to develop such standards. Standards are particularly important because methane systems are currently installed as aftermarket kits and are therefore not integrated in the original vehicle safety design and testing.

6. CNG FUELING

In the current absence of public fueling facilities for CNG cylinders, it is necessary that fleet operators install fueling systems for their vehicles. Two types of filling designs are used, termed fast fill and time fill systems. An installation may consist of time fill only, fast fill only, or both.

In the fast fill system, natural gas from a utility pipeline is routed through a dehydrating bed and a particulate filter into the compressor suction line. For the usual vehicle cylinder storage pressure of 2400 psi, the compressor discharges the gas at approximately 3600 psi into a bank of high pressure cylinders. The compressor discharge is equipped with a high pressure gauge and relief valve. The vehicle filling manifold at the storage bank outlet is comprised of fill-vent valves, flexible hoses and self-sealing quick disconnect couplings. The couplings on the filling manifold mate with couplings on the vehicles. When the fill-vent valve is

closed after vehicle filling, the gas in the hose is vented about ten feet above the ground remote from the operator. To achieve a full charge, the final pressure in the vehicle cylinders is varied depending upon ambient temperature; the pressure can be controlled manually or by use of a temperature compensating regulator. A vehicle can usually be filled in three to five minutes.

The time fill system is essentially the same as the fast fill installation except the bank of high pressure storage cylinders is not required. Also, the gas from the compressor is reduced in pressure to near the final filling value for the ambient temperature. Time filling is customarily accomplished overnight.

7. METHANE SUPPLY

The United States has sufficient proved and potential gas reserves, plus a synthetic natural gas (SNG) resource base, to support consumption near or above current levels through the rest of this century. However, to achieve these required production quantities, it will be necessary in future years to recover gas from more inaccessible formations and more hostile environments. In addition, conversion of coal and, perhaps, biomass and waste resources will have to be initiated.

Actual gas supply is dependent upon government policies, technological advancements, economic incentives, and capital availability. Due to these uncertainties, published gas supply projections for the next two decades vary widely. DOE's 1980 Annual Report to Congress forecasts declining gas production from the lower 48 states, balanced in part by nearly one trillion cubic feet per year of Alaskan gas becoming available in the 1985-86 time period. An important area of uncertainty is the future contribution of imported gas. Among six published projections for 1990, import estimates range from 1 to 4.3 trillion cubic feet annually, with the DOE estimate near the low end. To provide sufficient quantities of gas to meet projected demands, the DOE forecast relies heavily on gas produced from unconventional sources, particularly from Western tight sand reservoirs. The DOE forecast assumes that demand is constrained by conservation and restrictions in use, and concludes that more gas could be supplied if needed.

If gas for automotive use is confined to fleet applications, additional demand should be within the capability of the supply system to accommodate. Although occasional local and seasonal supply shortages may occur, as in the past, such events will be due primarily to storage and transmission system deficiencies rather than increased gas demand for vehicular use.

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